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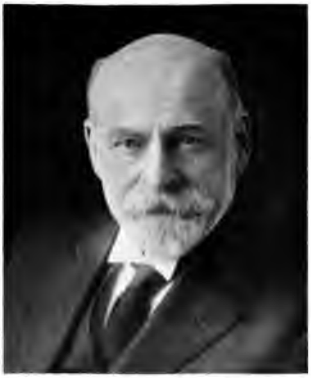

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PECULIAR PHENOMENA

OBSERVED IN QUARRYING.

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PHENOMENA OBSERVED IN QUARRYING.

BY W. H. NILES.

In working a quarry at Monson, Mass., some phenomena have been observed, which I trust will prove to be of scientific interest. For a few years, Mr. W. N. Flynt, proprietor of the quarry, and his foremen, have observed spontaneous fractures, movements and expansions of the rock. Mr. Flynt called the attention of some persons interested in science to these phenomena, yet no one made them a subject of special study. In November, 1870, he first called my attention to them by quite a full account of what had been observed. To me the facts were both new and interesting, and I have since made visits to the locality, that I might personally observe and study them. With the consent of Mr. Flynt and his foremen, I shall, in the present paper, give some account of the facts they have narrated to me, as well as of my own observations, in order that the subject may be more fully elucidated.[1]

The quarry is located in the belt of gneiss, which lies east of the red sandstone of the Connecticut Valley. From the city of Springfield, Mass., the quarry lies east about 4° north, and at a distance of about twelve miles and a half in a direct line. In going towards the quarry from Springfield, at a distance of about seven miles and a quarter in a direct course and in the town of Wilbraham, we come to the eastern edge of the red sandstone, and the base of the first range of hills forming the eastern boundary of the Connecticut Valley. These hills of metamorphic rock reach about six hundred feet in height. Crossing the range to the eastward, we descend into the valley in which the village of Monson is situated. The quarry is located on a low foot-hill at the eastern base of this first range. It extends from near the crest of the hill, over quite an area upon its southern end and western side, and where the surface is only gently inclined.

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[1] Since this paper was read, it has been so enlarged as to include the observations made up to the time of publication.

The rock at the quarry is chiefly gneiss. It is of fine, even-grained texture, quite free from impurities, and valuable for architectural purposes. The strike is north 10° east,[1] and the dip is west 10° north, at an angle of 80°. The rock is not divided by planes of stratification, but a set of parallel joints, cutting transversely to the stratification, divides it into regular beds, that at a distance, might be mistaken for strata. These beds incline only about 10° from a horizontal position, and are nearly parallel to the general surface of the hill. They vary in thickness from a few inches to several feet.

In quarrying, the beds are first broken at the lower or western side of the quarry. The stone is then obtained by first drilling small holes in rows, parallel to the strike of the stratification, and upon the upper surface, of the beds. Into these holes wedges are driven, thus breaking the rock into slabs of regular form. The beds are so free from seams, and the rock is so homogeneous in structure, that pieces of great length may be obtained in this manner. In working from the lower side of the quarry towards the upper, the edges of those portions of the beds which are still in position, rise above each other like successive steps. The edges of these steps form nearly straight lines, parallel to the strike of the strata. When these portions of the beds remain sometime without being worked, cracks frequently appear along these edges. If still allowed to remain undisturbed, the fractures become more extensive, and frequently break up large quantities of the excellent stock of the bed. It has been found by experience that when these cracks first appear their extension may be prevented, and the stock preserved from further injury, by making an opening in the bed, trending in easterly and westerly directions, thus cutting it across the strike, and at right angles to the ordinary working lines. It is evident that such an east and west opening could counteract only a force which is exerted in nearly north and south directions. That the force works in the direction of the strike of the strata, is still further evident upon the examination of some of these fissures. A single example may be sufficient for illustration.

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[1] Magnetic.

When at the quarry, April 29th, 1871, I observed an irregular fracture in a bed three feet and nine inches in thickness. The fracture was about sixty-one feet long. The northern portion of thirty-eight feet was nearly parallel to the strike, and the southern part of twenty-three feet curved to the eastward, and was accompanied by secondary fractures near it. Commencing at the northern end of the fracture and going southward, it would be noticed that at a few places it turned suddenly to the east, and immediately to the south again, thus making two right angles in its course. At these places the very short portions of the fracture trending eastward were wider than the long ones running southward, thus showing that the greatest movement had been from the north towards the south. At that time, April 29th, the southward movement had amounted to three-sixteenths of an inch; but when I visited the quarry July 7th, it had amounted to five-eighths of an inch, though at the time, the greatest width of the crack, at any place where it followed its general north and south course, was only one-fourth of an inch. Therefore the force which fractured the rock, had moved the relieved portion southward, more by three-eighths of an inch than it had been moved westward.

Spontaneous fractures, similar to the one described above, have been visible at the quarry whenever I have visited it. Sometimes they are quite large. I measured one, July 7th, which was full four inches wide.

Another series of phenomena is exhibited at the quarry, in the spontaneous elevation of the beds and the formation of miniature anticlinals. These elevations are common, and affect beds differing in thickness. In April I observed two anticlinals which had been recently formed. In one instance, a bed one foot eight inches thick had been elevated one inch and a half. The curvature of the upper surface of this bed was most distinctly visible. From the crest of this anticlinal to the base of the northern slope, the distance was twenty-three feet. The base of the southern slope could not be determined on account of the *debris* which had accumulated there. At one end of the crest there was a crack three-sixteenths of an inch wide, trending with the fold nearly east and west, but at the other end no fracture could be seen. In the other instance the bed was three inches thick, and at the centre had been elevated one inch. A fracture extended the entire length of the crest, which trended nearly east and west, as in the preceding instance.

On the afternoon of July 7th, a little anticlinal was formed while I was at the quarry. The bed was only two inches and three-fourths in thickness. The span of the arch from north to south was five feet five inches and a half. The length of the crest was five feet and a half, and a fracture extended the entire length of it. During the afternoon, the portion of the bed forming the crest was elevated three inches and a quarter. The situation showed that the force which caused the elevation, was not an artificial one used in working the quarry.

According to the testimony of the persons occupied at the quarry, explosions sometimes attend the fracturing and elevation of the beds. Mr. A. T. Wing, superintendent at the yard, says that cracking sounds are very frequently heard, especially after the work of the day, and the noise attending it has ceased. Though these sounds are more frequent in warm weather, yet they are heard in winter. These explosions sometimes throw dust into the air, and he has seen stones, weighing a few pounds, thrown several feet high by them. The sound of these explosions is sometimes as loud as the blasting of rock, and in a few instances it has been even louder. At one time, after the workmen had left the quarry, so loud a report was heard that they supposed the powder magazine had exploded. On hastening to the spot they found that it was not the powder, but the rock, which had exploded. A portion of a bed of nearly circular outline, and more than thirty feet in diameter and one foot in thickness, had been thrown up and broken. When they reached it, a portion at the centre was three feet above the surface from which it was broken, and the rock was still cracking and falling.

Another very interesting phenomenon is the expansion of the rock, as it is being quarried.

The most remarkable instance of this was observed in the autumn of 1869. By the use of more than twelve hundred wedges, a bed was split three hundred and fifty-four feet in length, in a line along the strike of the rock. The fracture extended from the northern and upper portion of the quarry southward, for the distance mentioned, but could be traced no further; so that this slab, which for three hundred and fifty-four feet had been fractured from the rock, was at its lower end, still attached to the bed, apparently as firmly as ever. The stone thus partly loosened, was eleven feet wide and three feet thick. At the upper portion of the fracture it was soon noticed, that the halves of the drill holes upon the freshly broken edge of the slab were not directly opposite their corresponding halves on the edge of the parent rock, but that they had been moved further up the hill, toward the north. At the extreme lower end, the wedges were still firmly held in the rock, and there was no perceptible evidence of any movement. But in passing from the lower end to the upper, the first evidence of expansion was shown in only a slightly oblique position of the corresponding halves of the drill holes. Passing on, the amount of unconformability of position increased regularly, until at the upper end it amounted to an inch and a half. Thus from the lowest wedge to the upper end, the stone was an inch and a half longer than that portion of the bed from which it had been broken. There is an abundance of testimony to this instance of expansion from those engaged at the quarry, and from those who came to the locality to see the curiosity. The stone was allowed to remain in the position above described for more than two months, and during that time it was exposed to warm and cold, and to wet and dry weather; but these changes of temperature and moisture produced no perceptible difference in the amount of the expansion. As the expansion was from the lower end to the upper, gravity could not have been a cause of the phenomenon.

In three instances, I have had the opportunity of observing the rock, when it has been split at shorter lengths in the manner described above. In each case the expansion was sufficient to admit of measurement.

Near the upper end of the quarry, four hundred holes had been drilled into a bed, making a row one hundred and twenty-eight feet long. When the wedges had been driven sufficiently to merely fracture the rock, and while most of them were still firmly held, the expansion amounted to one-sixteenth of an inch. The stone which had so expanded, was eleven feet wide, and three feet thick at the lower end, and five feet thick at the upper. In this example the upper end was the one attached, and the extension was southward.

Near the southern end of the quarry, a split thirty-three feet and a half long had been made. Here the slab was firmly attached to the bed at the lower end. Its width was six feet and nine inches, and its thickness one foot and eight inches. I was permitted to take out the wedges, when I found the expansion amounted to one eighth of inch at the upper end. I could distinctly see that it increased regularly in amount, from the lower end to the upper.

The other instance was in the working of a bed, the western edge of which extended in a direct line along the strike, without having been anywhere cut or fractured transversely. A row of wedges fifty-eight feet long was driven into holes upon the upper surface of the bed, and seven feet from its edge, thereby splitting the bed only along the line of the wedges. It was then necessary to cut from the western edge of the bed eastward to this fracture. The workmen attempted to do this by taking out a piece in the form of a triangle, the base of which was upon the edge of the bed, and the apex reached the upper end of the fracture. They found this a somewhat difficult task. The piece appeared to be held by something more than the tenacity of the rock, and it was necessary to break it into small pieces before it could be removed. When considerable stone had been cut away, cracking sounds were heard, and the remaining portion of the triangular mass was quickly fractured and easily removed. For two hours I had been watching the corresponding halves of the drill holes, at the upper end of the fracture first made by the wedges, to observe at what period of the work, the expansion, if any, should take place. The halves of the holes remained perfectly conformable in position, up to the time of the cracking sounds and the loosening of the stone, but immediately upon this taking place, those upon the edge of the slab were one-fourth of an inch further to the north, than those of the parent rock.

Prof. Johnston, of Middletown, Ct., has described[1] "*some spontaneous movements occasionally observed in the sandstone strata in one of the quarries at Portland, Ct.*" The movements there observed, he says, are the sliding of one stratum upon another. These occur whenever a stratum at the bottom of the quarry is first broken by excavating a channel in it, which trends in easterly and westerly directions. When such a channel has been cut only partly through the thickness of the stratum, the stone remaining at the bottom is crushed with a loud report, and the edge of the northern side moves southward about three-fourths of an inch. "These facts," he thinks, "plainly show that the strata of sandstone at this place are not, at the present time, perfectly at ease in their ancient bed," but he does not attempt to determine the cause.

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[1] Proc. Am. Association for the Advancement of Science. Eighth Meeting. 1854. p. 283.

National Magazine. Vol. III, No. 4. Oct., 1853. p. 362.

I am not aware that any other scientific man has observed and recorded facts similar to those given by Prof. Johnston. Probably such phenomena are to be observed at comparatively few localities. At many quarries the rock is so divided by loose joints, that it would quietly yield to a force, which at Monson would cause the phenomena described. From some statements made to me by persons interested in quarrying extensive and comparatively unbroken strata, I am inclined to believe that facts of a similar character might be collected.

When I visited Portland, the condition of the quarries gave me no opportunity for observing phenomena of the kind described by Prof. Johnston. I found, however, that the facts were well known to those who had been engaged there for a long time, through whom I was able to determine that the movements were from east of north towards west of south, or very nearly parallel to the directions of the movements at Monson. The force causing the phenomena at the two localities may be identical, for the manner of working the quarries at Portland gives no opportunity for observing fractures, elevations and expansions, like those so well shown at Monson.

Certain features in the structure of rocks, as cleavage, for example, have been considered, by eminent geologists, as evidences of severe compression; also, polished and striated surfaces have been regarded as proof of a sliding and slipping of parts. These features, however, afford no evidence of present action.

The phenomena observed seem to me to establish the following facts concerning the rocks at Monson: —

1. That they are compressed at the present time with great force.
2. That there is a lateral pressure exerted in northerly and southerly directions, but no indications of any acting in an easterly and westerly course.
3. That beds of very compact rock may be flexed and broken by lateral pressure, as seen in the actual formation of anticlinals.
4. That continued pressure does occasionally culminate in explosions and movements of the rock.
5. That even compact gneiss is, to a certain extent, compressible and elastic.
6. That whether lateral pressure originally brought the rock to its present compressed state or not, it now keeps it in that condition, excepting, of course, where it has been artificially removed; then the rock expands.

I believe that these and similar phenomena, will throw important light upon the more extensive folding, fracturing, and movement of rocks, and the elevation of mountains; but the discussion of these important relations is reserved with the hope of illustrating them by further observations, in a future paper.

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